

INDOOR AIR QUALITY ASSESSMENT

**Malden Fire Department, Maplewood Station
665 Salem Street
Malden, Massachusetts 02148**



Prepared by:
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Center for Environmental Health
Emergency Response/Indoor Air Quality Program
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Background/Introduction

At the request of Chris Webb, Director, Malden Health Department, the Massachusetts Department of Public Health (MDPH), Center for Environmental Health (CEH), conducted an indoor air quality assessment at the Malden Fire Department (MFD) Maplewood Station, located at 665 Salem Street, Malden Massachusetts. The request was prompted by occupant complaints of poor indoor air quality and mold concerns from chronic water damage. On October 20, 2005, a visit was made to the station by Cory Holmes, an Environmental Analyst in CEH's Emergency Response/Indoor Air Quality (ER/IAQ) Program to conduct an indoor air quality assessment. Mr. Holmes was accompanied by Mr. Webb during the assessment.

The station is a two-story red brick building with a slate roof that was constructed in 1903. The MFD currently leases the space from the Mystic Valley Charter School, which recently purchased the property. The ground floor contains the engine bay, the patrol room, and storage areas. The second floor contains the bunkhouse, shower rooms, a weight room, a kitchen and lounge. Windows are openable throughout the building. The station has two engine bays for vehicle access. A stairwell connects the engine bays to the second floor. A fire pole with access to the engine bay is located in the second floor hallway. The building has undergone some interior renovations over the years and roof repairs have been made to prevent/reduce leakage. The building also contains an Annex, which is used by the Mystic Valley Charter School for a library. The Annex, located on the ground floor, was not assessed by MDPH staff.

Methods

Air tests for carbon dioxide, carbon monoxide (CO), temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor. Air tests for ultrafine particulates (UFPs) were taken with the TSI, P-Trak TM Ultrafine Particle Counter Model 8525. Moisture content of porous building materials (e.g., ceiling tiles, wooden trim, wall plaster), were measured with a Delmhorst, BD-2000 Model, Moisture Detector with a Delmhorst Standard Probe.

Results

The station is staffed 24 hours a day, seven days a week and has an employee population of 28 (7 per shift). The station can be visited by up to 10 members of the public on a daily basis. The tests were taken under normal operating conditions. Test results for general air quality parameters (i.e., carbon dioxide, temperature and relative humidity) appear in Table 1. Moisture sampling results are also included in Table 1. Test results for UFPs and CO were taken prior to and after the operation of emergency response vehicles conducting a simulated call. These results are listed in Table 2.

Discussion

Ventilation

It can be seen from the Table 1 that carbon dioxide levels were at or below 800 parts per million (ppm), indicating adequate air exchange in the areas surveyed (Table 1). However it is important to note that the station does not have any means of mechanical

ventilation to introduce outside air. Heating and air conditioning is provided by air handling units (AHUs) located in the attic (Picture 4). The AHUs do not have the capacity to introduce outside air but *recirculate* air only. AHUs are ducted to wall mounted air diffusers (Picture 5). Ceiling mounted return vents in the hallways (Picture 6), draw air back to the AHUs via ductwork. These systems were operating during the assessment. MFD personnel could not confirm that a preventive maintenance program was in place for air handling equipment.

The station was originally configured in a manner to use cross-ventilation to provide comfort for building occupants. The building is equipped with windows on opposing exterior walls. In addition, the building has hinged windows located above the hallway doors. These hinged windows (called transoms, Pictures 1 and 2) enable building occupants to close the hallway doors while maintaining a pathway for airflow. This design allows for airflow to enter an open window, pass through an office and subsequently pass through the open transom. Airflow then enters the hallway, passing through the opposing open office transom, into the opposing room and finally exits the building on the leeward side (opposite the windward side) (Figure 1). With all windows and transoms open, airflow can be maintained in a building regardless of the direction of the wind. The system fails if the windows or transoms are closed (Figure 2). In this case, the use of transoms has been nullified by the sealing of internal windows, preventing airflow (Picture 3).

A vehicle exhaust ventilation system is installed in the engine bays to remove carbon monoxide and other products of combustion; the system is described in detail under the Vehicle Exhaust portion of this report.

To maximize air exchange, the MDPH recommends that both supply and exhaust ventilation operate continuously during periods of occupancy. In order to have proper ventilation with a mechanical ventilation system, the systems must be balanced subsequent to installation to provide an adequate amount of supply air to the interior of a room while removing stale air from the room. It is recommended that HVAC systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994). The date of the last servicing and balancing was not available at the time of the assessment.

The Massachusetts Building Code requires a minimum ventilation rate of 20 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the

majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, please see [Appendix A](#).

Temperature readings in occupied areas ranged from 61° F to 68° F, which were below the MDPH recommended comfort range. The MDPH recommends that indoor air temperatures be maintained in a range of 70° F to 78° F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply.

Relative humidity measurements ranged from 38 to 41 percent, which were within or very close to the MDPH recommended comfort guidelines. The MDPH recommends that indoor air relative humidity is comfortable in a range of 40 to 60 percent. During winter months outdoor relative humidity levels tend to drop. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a common problem during the heating season in the northern part of the United States.

Microbial/Moisture Concerns

The building has reportedly experienced problems with water penetration, most notably from leaks through the slate roof (Picture 7). Water penetration throughout the building was evidenced by damaged/stained plaster, wood, ceiling tiles, peeling paint and efflorescence (Pictures 8 through 11). It was reported that roof repairs in several areas were

recently conducted. However, wet ceiling tiles were found in the patrol room and a bucket with standing water was observed in the attic (Picture 12), which indicates continuing leaks.

Water-damaged ceiling tiles can provide a source of mold and should be replaced after a water leak is discovered and repaired. Efflorescence is a characteristic sign of water damage to building materials such as brick or plaster, but it is not mold growth. As moisture penetrates and works its way through mortar around brick, water-soluble compounds dissolve, creating a solution. As the solution moves to the surface of the brick or mortar, water evaporates, leaving behind white, powdery mineral deposits. This condition indicates that water from the exterior has penetrated into the building.

Another means for water penetration into the building is through the building envelope. Missing/damaged mortar around brickwork on the exterior of the building was observed in numerous areas (Pictures 13 through 16). This damage is particularly noticeable along the base of the building where water splashes against exterior walls because the gutter and downspout systems have been removed (Pictures 17 through 20).

Repeated water damage to porous building materials (e.g., wallboard, ceiling tiles, carpeting) can result in microbial growth. The US Environmental Protection Agency (US EPA) and the American Conference of Governmental Industrial Hygienists (ACGIH) recommend that porous materials be dried with fans and heating within 24 to 48 hours of becoming wet (US EPA, 2001; ACGIH, 1989). If not dried within this time frame, mold growth may occur. Once mold has colonized porous materials, they are difficult to clean and should be removed.

In order for building materials to support mold growth, a source of moisture is necessary. Identification and elimination of water moistening building materials is

necessary to control mold growth. Porous materials with increased moisture content over normal concentrations may indicate the possible presence of mold growth. Identification of the location of materials with increased moisture levels can also provide clues concerning the source of water supporting mold growth. In an effort to ascertain moisture content of porous building materials, samples were taken in areas most likely impacted by water damage, primarily in the patrol room and second floor restroom.

Water content in porous materials was measured with a Delmhorst, BD-2000 Model, Moisture Detector with a Delmhorst Standard Probe. The probe was inserted into the surface of building materials. The Delmhorst probe is equipped with three lights as visual aids to determine moisture level. Readings, which activate the green light, indicate a sufficiently dry level, those that activate the yellow light indicate borderline conditions and those that activate the red light indicate elevated moisture content. Elevated moisture measurements were recorded in ceiling tiles in the patrol room (Table 1) indicating that a continuing source of water penetration exists.

Vehicle Exhaust

Under normal conditions, a firehouse can have several sources of environmental pollutants present from the operation of fire vehicles. These sources of pollutants can include:

- Vehicle exhaust containing carbon monoxide and soot;
- Vapors from diesel fuel, motor oil and other vehicle liquids which contain volatile organic compounds;
- Water vapor from drying hose equipment;

- Rubber odors from new vehicle tires; and
- Residues from fires on vehicles, hoses and fire-turnout gear.

The process of combustion produces a number of pollutants, depending on the composition of the material. In general, common combustion emissions can include carbon monoxide, carbon dioxide, water vapor and smoke. Of these materials, carbon monoxide can produce immediate, acute health effects upon exposure. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within the rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

The US Environmental Protection Agency has established National Ambient Air Quality Standards (NAAQS) for exposure to carbon monoxide in outdoor air. Carbon monoxide levels in outdoor air must be maintained below 9 ppm over a twenty-four hour period in order to meet this standard (US EPA, 2000). *Carbon monoxide should not be present in a typical, indoor environment.* If it is present, indoor carbon monoxide levels should be less than or equal to outdoor levels. Outdoor carbon monoxide concentrations were non detectable or ND (Table 2). Carbon monoxide levels measured in the WFD were ND with the exception of the stairwell, which measured 1 ppm (Table 2), after the operation of fire fighting vehicles.

The combustion of fossil fuels can produce particulate matter that is of a small diameter (10 μm), which can penetrate into the lungs and subsequently cause irritation. For this reason a device that can measure particles of a diameter of 10 μm or less was also used

to identify pollutant pathways from vehicles into the occupied areas. Inhaled particles can cause respiratory irritation.

MDPH air monitoring for airborne particulate was conducted with a TSI, P-Trak™ Ultrafine Particle Counter (UPC) Model 8525, which counts the number of particles that are suspended in a cubic centimeter (cm^3) of air. This type of air monitor is useful as a screening device, in that it can be used as a tracker to identify the source of airborne pollutants by counting the actual number of airborne particles. The source of a producer of particles can be identified by moving the UPC through a building towards the highest measured concentration of airborne particles. Measured levels of particles/ cm^3 of air increases as the UPC is moved closer to the source of particle production.

The primary purpose of these tests at the station was to identify and reduce/prevent pollutant pathways. Air monitoring for ultrafine particles was conducted around each door with access to the engine bay as well as several areas within the station. Measurements were taken prior to and after apparatus operation. The highest reading for UFPs was taken in the engine bay after vehicle operation. These measurements would be expected during the normal operation of motor vehicles in an indoor environment. However, several elevated readings were measured in adjacent areas identifying pathways for the migration of vehicle exhaust into occupied areas (Table 2).

As mentioned previously, the station is equipped with a mechanical exhaust system to remove exhaust from the engine bay during vehicle idling. The system in use at the station connects directly to the tail pipe of the engine via a pressurized cuff (Picture 21). As the vehicle exits the station, the cuff, which is pulled on a runner, trips a trigger releasing the cuff. The system is designed to collect vehicle exhaust directly at the source and remove it

from the building, minimizing exposure. Although the engine bay is equipped with local exhaust ventilation, a number of pathways for vehicle exhaust and other pollutants to move from the engine bay into occupied areas on both the first and second floors were identified:

- No door separating the engine bay from the stairwell leading to the upstairs exists (Picture 22).
- A significant space below the door at the top of the stairwell was observed (Picture 23).
- Spaces were observed around the firepole.
- The door to the patrol room does not close completely and has no handle on the inside to pull shut (Picture 24).
- The ceiling/walls of the engine bay are penetrated by utility holes (Pictures 25 and 26). These holes can present potential pathways into occupied areas if they are not airtight.

Each of these pathways can allow air to move from the engine bay to occupied areas of the station. In order to explain how engine bay pollutants may be impacting the second floor and adjacent areas, the following concepts concerning heated air and creation of air movement must be understood.

- ◆ Heated air will create upward air movement (called the stack effect).
- ◆ Cold air moves to hot air, which creates drafts.
- ◆ As heated air rises, negative pressure is created, which draws cold air to the equipment creating heat (e.g., vehicle engines).
- ◆ Combusted fossil fuels contain heat, gases and particulates that will rise in air. In

addition, the more heated air becomes the greater airflow increases.

- ◆ The operation of HVAC systems (including rest room exhaust vents) can create negative air pressure, which can draw air and pollutants from the engine bays.

Each of these concepts has influence on the movement of air. As motor vehicles operate indoors, the production of vehicle exhaust in combination with cold air moving from outdoors through open exterior doors into the warmer engine bay can place the bay under positive pressure. Positive pressure within a room will force air and pollutants through spaces around doors, utility pipes and other holes in walls, doors and ceilings. It was reported by occupants that when the engine bay garage doors open, positive pressure forces the second floor doorway open. Once airborne pollutants from the engine bay enter occupied areas on the second floor they can be entrained (drawn into) the HVAC system and distributed throughout the station. To reduce airflow into the second floor, sealing/reduction of these pollutant pathways should be considered.

Other IAQ Evaluations

MFD staff could not identify the last filter change or preventative maintenance done on the HVAC equipment. MDPH staff inspected HVAC filters, which are located in the ceiling-mounted return vents. The filters were of a type that provides minimal filtration and were occluded with dust and debris (Picture 27). In order to decrease aerosolized particulates, higher efficiency, disposable filters can be installed. The dust spot efficiency is the ability of a filter to remove particulates of a certain diameter from air passing through the filter. Filters that have been determined by ASHRAE to meet its standard for a dust spot efficiency of a minimum of 40 percent would be sufficient to reduce airborne particulates

(Thornburg, D., 2000; MEHRC, 1997; ASHRAE, 1992). Note that increased filtration can reduce airflow produced by the univent through increased resistance (called pressure drop). Prior to any increase in filtration, AHUs should be evaluated by a ventilation engineer to ascertain whether they can maintain function with more efficient filters.

A number of exhaust and return vents in common areas and in restrooms had accumulated dust (Picture 28). If exhaust vents are not functioning, backdrafting can occur, which can re-aerosolize dust particles. In addition, these materials can accumulate on flat surfaces (e.g., desktops, shelving and carpets) in occupied areas and subsequently be re-aerosolized, causing further irritation.

Finally, exposed fiberglass insulation was observed in the weight room (Pictures 29). Fiberglass insulation can be a source of skin, eye and respiratory irritation to sensitive individuals.

Conclusions/Recommendations

The conditions noted at the MFD Maplewood Station raise a number of indoor air quality issues. The general building conditions, chronic water penetration, maintenance and pathways for engine bay pollutants to migrate to occupied areas, present conditions that could degrade indoor air quality. Some of these conditions can be remedied by the actions of building occupants. Other remediation efforts will require alteration to the building structure and equipment. For these reasons, a two-phase approach is suggested for remediation. The first consists of **short-term** measures to improve air quality and the second consists of **long-term** measures that will require planning and resources to adequately address the overall indoor air quality concerns.

In view of the findings at the time of the visit, the following **short-term** recommendations are made:

1. Install doors at the base of the stairwell in the engine bay. Ensure doors around engine bays and at the top of stairwell fit completely flush with threshold. Seal doors on all sides with foam tape, and/or weather-stripping. Consider installing weather-stripping/door sweeps on both sides of doors with access to the engine bay to provide a dual barrier. Ensure tightness of doors by monitoring for light penetration and drafts around doorframes.
2. Install handle on the interior side of patrol room door (Picture 30).
3. Install automatic closure hardware on stairwell doors (Picture 31).
4. Consider removing fire pole and sealing access hole. If not removed, install clamshell-type closures around firepole to prevent pollutant pathways.
5. Ensure utility holes are properly sealed in both the engine bay and their terminus to eliminate pollutant paths of migration.
6. Work with Malden City officials to develop a preventative maintenance program for all HVAC equipment department wide, including local exhaust systems for engine bays.
7. Change filters for HVAC equipment as per the manufacturer's instructions or more frequently if needed. Consider upgrading to higher efficiency pleated filters.
8. Use openable windows in conjunction with HVAC system to increase air exchange. Care should be taken to ensure windows are properly closed at night and weekends to avoid the freezing of pipes and potential flooding. Consider reinstalling openable

windows in the second floor hallway (Picture 3) to use in conjunction with transoms to provide cross-ventilation.

9. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).
10. Continue to work with roofing contractor to make repairs as needed to prevent water penetration. Particular attention should be made to the exterior roof/flashing outside the patrol room shown in Pictures 13 and 18.
11. Replace/repair any remaining water-stained ceiling tiles and building materials. Examine the area above and around these areas for mold growth. Disinfect areas of water leaks with an appropriate antimicrobial.
12. Contact a masonry firm or general contractor to repair holes/breaches in exterior walls to prevent water penetration, drafts and pest entry.
13. Clean exhaust and return vents periodically to avoid the build-up of excessive dust.
14. Make repairs to walls in weight room to prevent exposure to fiberglass insulation.
15. For further building-wide evaluations and advice on maintaining public buildings, see the resource manual and other related indoor air quality documents located on the MDPH's website at <http://www.state.ma.us/dph/beha/iaq/iaqhome.htm>.

The following **long-term measures** should be considered:

1. Consider having exterior walls re-pointed and waterproofed to prevent water intrusion. This measure should include a full building envelope evaluation.
2. Consider total roof replacement including the removal of historical “patches”.
3. Install gutters and downspouts as the building was originally designed, to direct water away from the building.

References

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Picture 1



Transom over Bunkroom Door

Picture 2

Internal Windows

Transom over Bunkroom Door



Windows (now sealed) and Transoms in Second Floor Hallway, Block Arrow Indicates Intended Airflow

Picture 3



Sealing of Internal Windows on Second Floor Preventing Airflow

Picture 4



One of Two AHUs Located in the Attic

Picture 5



Wall-Mounted Supply Vents in Bedroom

Picture 6



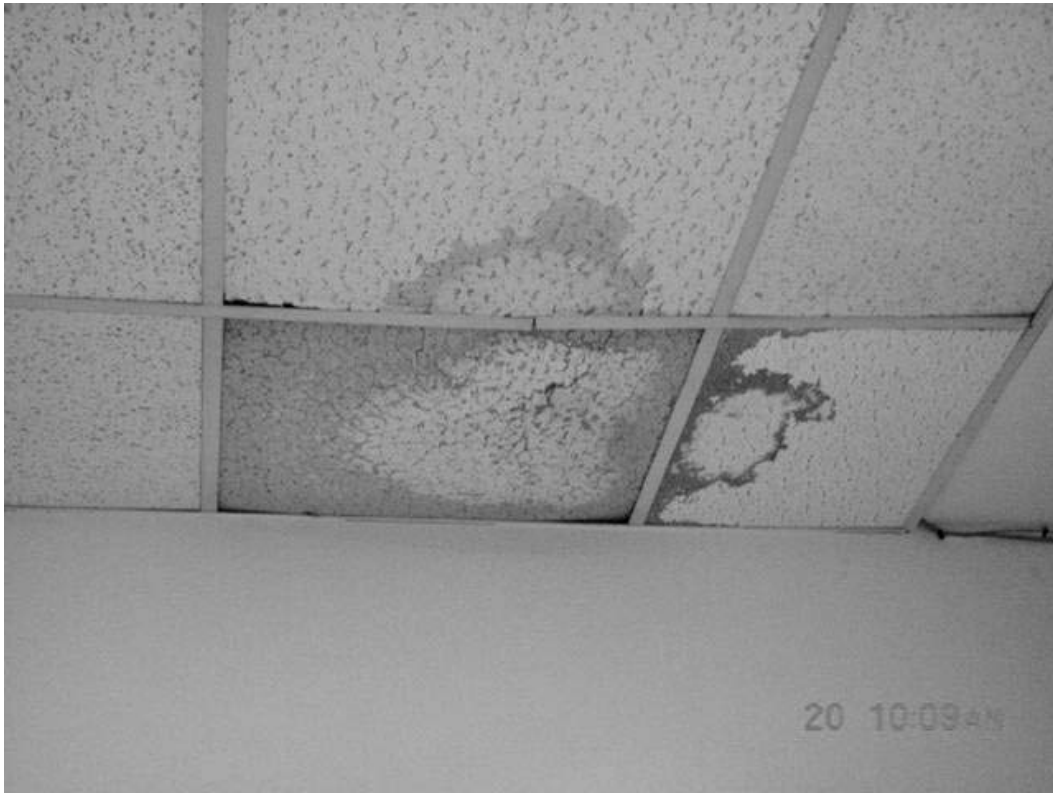
Ceiling-Mounted Return Vent in Hallway, Note Missing Tiles

Picture 7



Slate Roof, Note Tar Indicating Patches and Damaged “Sliding” Shingles

Picture 8



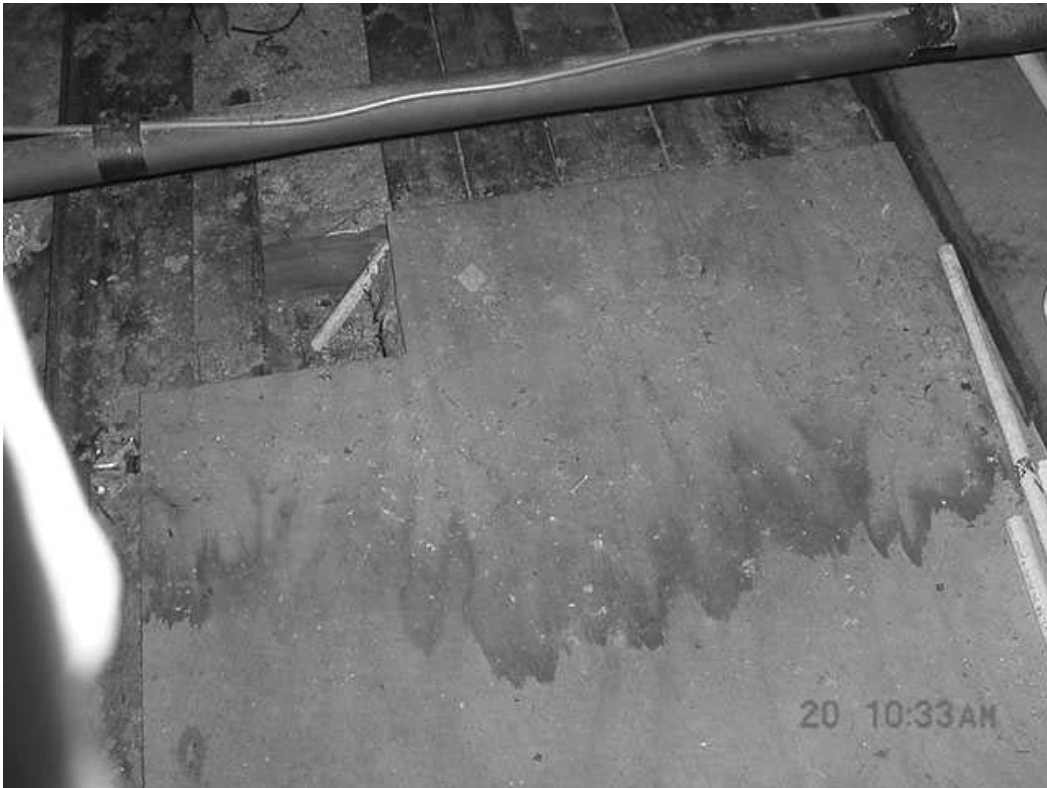
Water Damaged Ceiling Tiles in Second Floor Hallway

Picture 9



Water Damaged Ceiling Tiles in Bunkroom (the “Blue” Room)

Picture 10



Water Stained Floorboard in Attic

Picture 11



**Water Damaged Ceiling Tiles, Plaster, Wood, Peeling Paint and Efflorescence
In Second Floor Bathroom**

Picture 12



Bucket With Standing Water in Attic

Picture 13



Water Damaged Wood and Missing Damaged Mortar near Roof of Patrol Room Entrance

Picture 14



Missing Damaged Mortar near Second Floor Bunkroom Window

Picture 15



Heavy Moss Growth and Missing Damaged Mortar at Base of Building

Picture 16



Missing Damage Mortar around Brick at Base of Building

Picture 17



Missing Downspout

Picture 18



Sections of Roof over Patrol Room With no Gutters/Downspouts, Note Rotted Wood and Missing/Damaged Mortar (also shown in Picture 13)

Picture 19



Missing Downspout, Note Water Damage/Staining to Wall

Picture 20



Sections of Roof With no Gutters/Downspouts

Picture 21



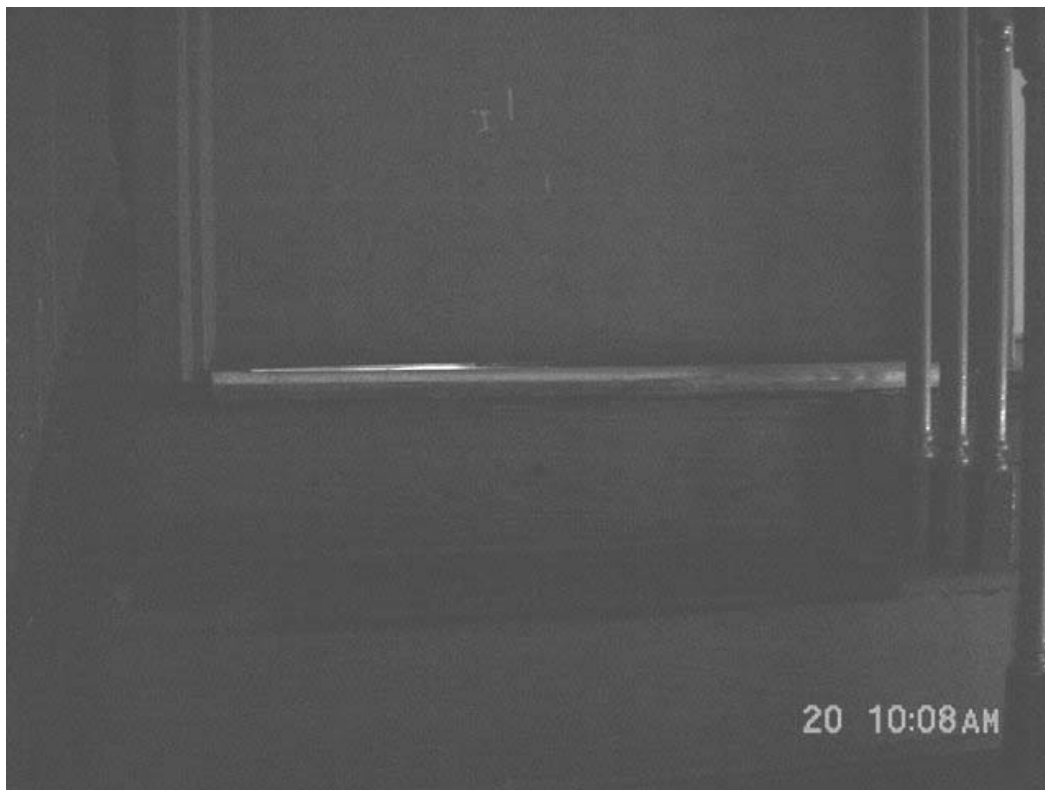
Local Exhaust System With Cuff That Attaches to Tailpipe

Picture 22



Stairwell off the Engine Bay With no Door

Picture 23



Approximately 1-inch Space beneath Stairwell Door off the Engine Bay

Picture 24



Patrol Room Door (Interior Side)

Picture 25



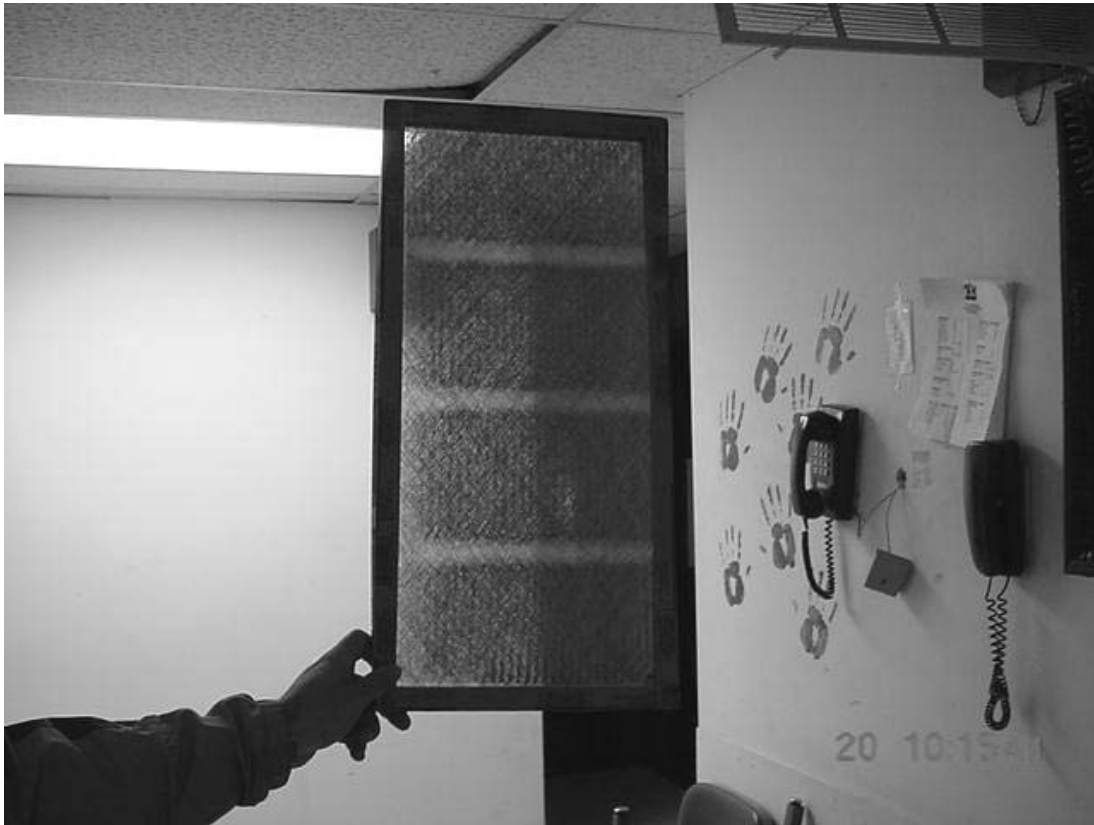
Hole in Engine Bay Ceiling

Picture 26



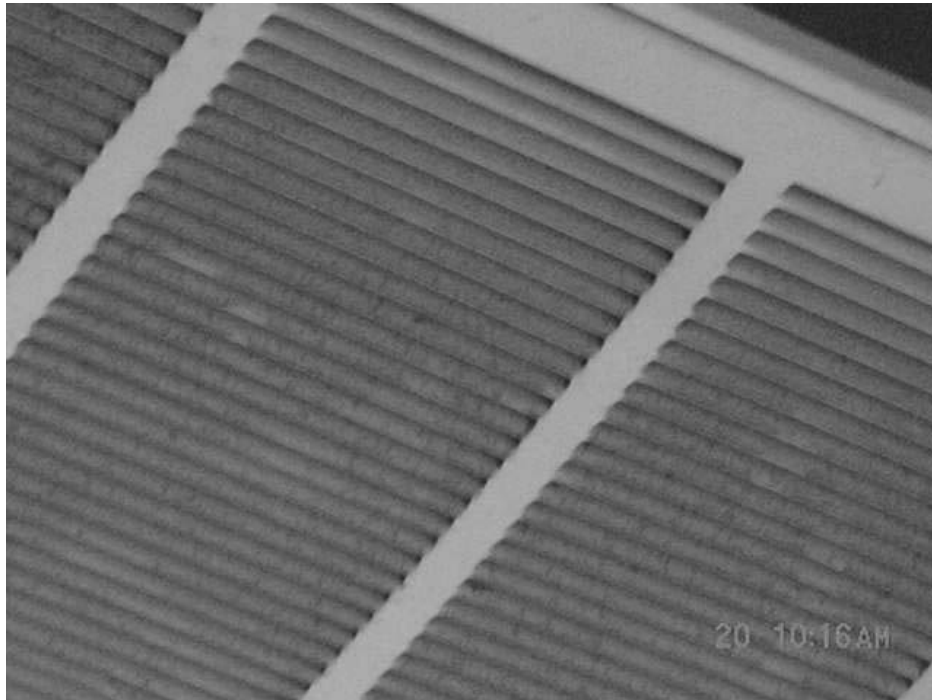
Utility Holes in Engine Bay Ceiling

Picture 27



Dust Occluded Filter Installed in Ceiling-Mounted Return Vent

Picture 28



Dust Accumulation on Return Vent in Second Floor Hallway

Picture 29



Exposed Fiberglass Insulation in Weight Room

Picture 30



Handle Installed on Exterior Side of Patrol Room Door

Picture 31



Automatic Door Closure Hardware

TABLE 1

Indoor Air Test Results – Malden Fire Department, Maplewood Station, Malden, MA – October 20, 2005

Location	Carbon Dioxide (*ppm)	Temp (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation		Remarks
						Supply	Exhaust	
Background	403	60	35					Scattered clouds, winds WNW 10-15 mph, mostly sunny
Engine Bay	510	60	39	5		Y	Y	No door to stairwell, local exhaust system, 2 garage doors, utility holes in ceiling, spaces under bathroom door (for school)
Patrol Room	510	61	41	0	Y	N	N	2 WD CT-Saturated/high moisture content, wood trim/plaster walls-low moisture content, no handle on inside door-does not shut completely, AC in window
Stairwell	537	61	38	0		N	N	Door propped open, spaces under door
2 nd Floor Hallway	550	66	40	0		N	N	Ceiling-mounted return vent-filters: minimal filtration, dirty, missing CTs
Blue Room	560	67	41	0	Y	N	N	WD CTs
Captain's Room	800	68	37	0	Y	N	N	
TV Room	532	65	34	0	Y	N	N	Door to stairwell left open, window open, AC

* ppm = parts per million parts of air

Comfort Guidelines

Carbon Dioxide - < 600 ppm = preferred
600 - 800 ppm = acceptable
> 800 ppm = indicative of ventilation problems

Temperature - 70 - 78 °F

Relative Humidity - 40 - 60%

TABLE 1

Indoor Air Test Results – Malden Fire Department, Maplewood Station, Malden, MA – October 20, 2005

Location	Carbon Dioxide (*ppm)	Temp (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation		Remarks
						Supply	Exhaust	
Recreation Room	500	66	37	0	Y	N	N	2 WD CTs, pool table
Kitchen	427	66	37	0	Y	N	N	Window open
Weight Room	427	66	37	0	Y	N	N	Exposed fiberglass insulation-unfinished walls, gaps beneath doors to fire pole access way, spaces around firepole
Private's Room	475	67	38	0	Y	N	N	
Attic								2 AHUs-no fresh air supply/exhaust, WD floor boards/beams, plastic sheeting, bucket with standing water

* ppm = parts per million parts of air

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 2

**Indoor Air Test Results* for Ultrafine Particulates and Carbon Monoxide
Malden Fire Dept. Maplewood Station, Malden, MA – October 20, 2005**

Location	Carbon Monoxide (**ppm) Before	Carbon Monoxide (**ppm) After	Ultrafine Particulates 1000p/cc³ Before	Ultrafine Particulates 1000p/cc³ After	Comments
Background (outdoor)	ND	ND	8.5		Scattered clouds, winds WNW 10-15 mph, mostly sunny
Engine Bay	ND	ND	8.5	92.0	No door to stairwell, local exhaust system, 2 garage doors, utility holes in ceiling
Patrol Room	ND	ND	8.3	48.0	No handle on inside door-does not shut completely
Stairwell	ND	ND	8.3	106.0	Exhaust emissions “trapped” in stairwell, spaces under door
2 nd Floor Hallway	ND	1	8.3	25	Return vent-drawing air from stairwell, door opened by positive pressure when bay doors open
Blue Room	ND	ND	6.4	10.3	
Captain’s Room	ND	ND	4.8	10.7	
TV Room	ND	ND	5.6	11.1	Door to stairwell left open, window open
Recreation Room	ND	ND	6.4	11.5	
Kitchen	ND	ND	6.8	12.0	Window open
Weight Room	ND	ND	7.4	9.3	Spaces beneath doors to fire pole access way, spaces around firepole
Private’s Room	ND	ND	4.9	14.4	

**** ppm = parts per million parts of air**

*** testing before and after starting diesel engines and response vehicles for simulated call**

Figure 1

Cross Ventilation in a Building Using Open Windows and Transoms

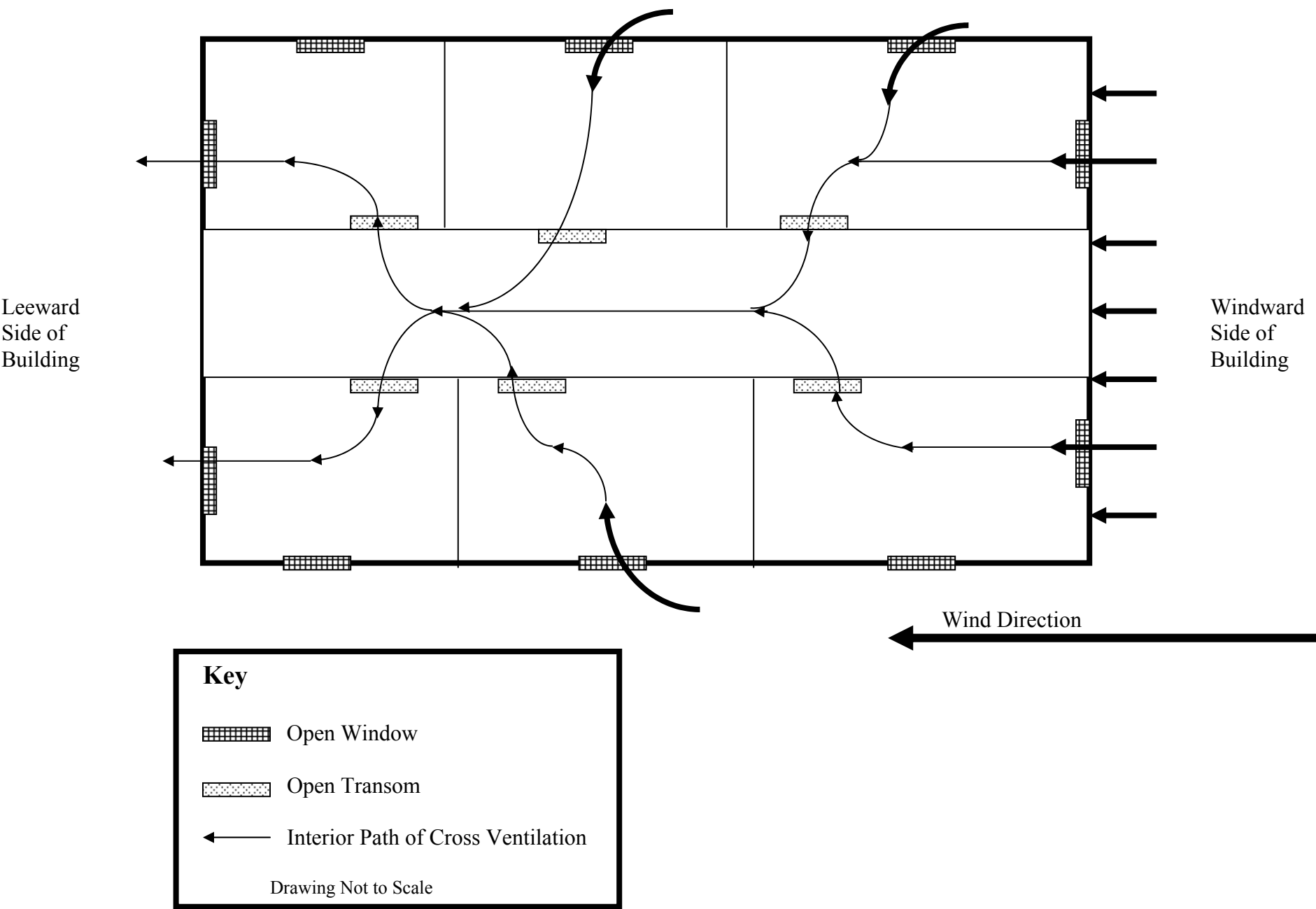


Figure 2

Inhibition of Cross Ventilation in a Building with Several Windows and Transoms Closed

